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INITIAL FIELD APPLICATION/TESTS OF TELEMETRY SYSTEM TO MONITOR STABILITY OF HIGHWALL AND TAILINGS AREAS AT THE SYNCRUDE OILSANDS OPEN PIT MINE

M.Y. Fisekci and N.J. Stuart
Calgary Coal Research Laboratory

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INITIAL FIELD APPLICATION/TESTS OF TELEMETRY SYSTEM TO MONITOR STABILITY OF HIGHWALL AND TAILINGS AREAS AT THE SYNCRUDE OILSANDS OPEN PIT MINE

by

M.Y. Fisekci* and N.J. Stuart*

ABSTRACT

CANMET/CRL had previously developed, under a contract with Ecological and Resources Consultants Ltd., a radio telemetry system for monitoring tiltmeters for use at an hydraulic mine at Sparwood, B.C. This system has now been installed with minimal modification to monitor highwall and tailings dam stability at the Syncrude oil sands operation near Fort McMurray, Alberta.

This report describes the recalibration of the tiltmeters, their installation and the initial field tests of the system in this electromagnetically noisy environment. Recommendations for the future expansion of the system are outlined.

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*Research Scientist, Calgary Coal Research Laboratory, CANMET, Energy, Mines and Resources Canada, Calgary, Alberta

PREMIÈRE APPLICATION SUR LE TERRAIN MISE À L'ESSAI D'UN SYSTÈME DE TÉLÉMÉTRIE POUR CONTRÔLER LA STABILITÉ DES PAROIS DU BARRAGE DE RETENUE DES RÉSIDUS DE L'EXPLOITATION À CIEL OUVERT DE SABLES BITUMINEUX DE LA SYNCRUDE

par

M.Y. Fisekci* et N.J. Stuart*

RÉSUMÉ

CANMET/LRC a antérieurement mis au point, dans le cadre d'un contrat avec Ecological and Resources Consultants Ltd., un sytème de télémétrie par des procédés radioélectriques pour surveiller les télémètres qui seront utilisés dans une mine hydraulique à Sparwood (B.C.). Le système a subi des modifications minimes avant d'être mis en place pour assurer la surveillance des parois du barrage de retenue des résidus de l'exploitation à ciel ouvert de sables bitumineux de la Syncrude près de Fort McMurray en Alberta.

Le rapport présente une description du réétalonnage et de l'installation des télémètres, et des premiers essais du système, sur le terrain, dans un environnement electro-magnétique bruyant. L'auteur fait des recommandations concernant le développement du système dans l'avenir.

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*Chercheur scientifique, Laboratoire de recherche sur le charbon de Calgary, CANMET, Énergie, Mines et Ressources Canada, Calgary (Alberta).

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INTRODUCTION

This report describes the initial R & D work to install and test the telemetry system at the Syncrude mine, near Fort McMurray, Alberta. It provides information about the equipment installed and initial test results. The project involved the monitoring of geotechnical stability in both the highwall and tailings disposal areas of the mine. This work also included training site engineers in the use of the equipment. Also included is a description of the geotechnical problems and the future development of this project.

PROBLEM DEFINITION

M.Y. Fisekci and A.Chrzanowski visited the site on May 30, 1985 for the purpose of discussion and reconnaissance. The nature of the telemetry system was explained to the site personnel who in turn outlined the principal areas in which they beleived it might be applicable. A.E. Fair, Supervisor of Syncrude Geotechnical Group expressed interest and willingness to cooperate in testing the system with a view to possible future integration with the mines existing monitoring program. The visit included inspecting the potential monitoring sites so that preliminary plans could be made to adapt the system to the site. These adaptions were for the most part minor details such as quick mounting adaptors for the tiltmeters used on the highwall and the selection of radio antennae.

GEOTECHNICAL PROBLEMS AT SYNCRUDE

Geotechnical problems exist in two areas of the mine, the highwall of the pit and the tailings dam. In the case of the highwall various mechanisms of failure have been observed the most significant being shallow block failure. These occur on clay bands which are part of channel structures and cause problems when they dip into the pit. The principal concern is the possibility of losing one of the four multi-million dollar draglines with the ensuing loss of production and underuse of downstream.

Currently the elaborate monitoring program is labour intensive. It involves attempting to map out dangerous structures (both superficially and by drilling) and monitoring ground movement by the measurement of shear displacement in boreholes. The later, being discontinuous and expensive, is seen as an area that may be augmented or even replaced by the remotely monitored tiltmeter system disussed here.

The second area of geotechnical interest is the stability of the tailings dyke. The tailings dyke at the Syncrude site consists of a 20 km long structure that impounds the pond in which the solid waste (sand) from the extraction process settles out from the slurry in which it is transported. As mining progresses the tailings accumulate and the dykes must be built up accordingly. Thus the stresses around the tailings dam increase monotonically with time. Parts of the tailings dam are underlain by the Clearwater Formation, a marine clay, which it is believed will flow under moderate loads from the tailings dam. If or when such failure seems imminent at any point on the dam the situation might well require serious remedial action. It might also dictate the ultimate height to which the dam may safely be built. It is believed that tilt readings around the base of the dam would reveal the occurrence of any movement. Currently monitoring work necessitates a substantial drive to take readings, limiting the frequency with which readings can be taken.

THE TELEMETRY SYSTEM

The system was originally developed to monitor ground subsidence over an underground coal mine at Sparwood, B.C. The system was designed to operate in severe conditions in mountain terrain with high demands being made in terms of temperature stability and battery life. Three years of field testing and development showed the system to be reliable. Numerous reports, especially Fisekci "Subsidence R & D Over Thick and Steep Seams Hydraulic Mining" give details and a seminar was given on the system on August 31, 1985 by M.Y. Fisekci, A. Chrzanowski, B. Kurz and A. Makosinski.

COMMUNICATION

The system consists of one master station and up to 256 slave stations. Communication takes place by a polling system. Communications protocol, the logical design of the communication, is controlled by software built into both master and slave stations. These programs allow the master station to initiate communication by issuing a "wakeup" signal to the slaves and the address (identification number) of the slave to be polled. This causes the slave to be brought out of a power saving state and be capable of interrogation. The protocol also takes care of such things as error detection and correction, and "redialling" a slave that failed to respond. The data is modulated by the FSK (frequency shift key) method. It is important to note that all communication is initiated by the master which interrogates one slave at a time and that the system is designed to recover as far as possible from any loss of communication.

THE MASTER STATION

The master station is based on an IBM-PC which runs a program under the normal operating system. This program allows manual interrogation of the slaves as well as monitoring at predetermined intervals. The received data is displayed, printed, stored on floppy disc and/or made available to an outside user by modem. The specialized hardware resides in a small cabinet that plugs into a standard port at the rear of the PC. This contains RF circuitry, the FSK chip and such things as an aerial relay so that the same antenna may be used for transmission and reception. The system reboots automatically after a power failure with no loss of data.

THE SLAVE STATION

The central component within a slave station is a microprocessor (note it has a "military specification" temperature range) which runs a program stored in EPROM (a non volatile read only memory). The normal state of the slave is a low power listening mode. On detection of a polling request from the master the slave switches on the power to other boards such as the transmitter and the data acquisition devices. The microprocessor reads the various input analogue channels by switching a multiplexer on the input to the analogue to digital converter. Analogue channels may be used to read (and thus compensate for) battery condition and temperature. Four

channels are used if two biaxial tiltmeters are to be read. Initially, however, only one tiltmeter per slave has been used (using two channels). Other components of the slave station are the rechargeable batteries and communications equipment such as is used in the master station.

Of the stations used five were prototype "old" stations (slaves 0-4) and slaves 5-7 were updated "new" stations.

THE TILTMETERS

Prior to the work at Sparwood a major study was carried out to find suitable tiltmeters at an acceptable price and to calibrate the thermal and drift properties of the selected tiltmeters. The selected tiltmeters are made by Terratechnology of Seattle. By changing the gain on the input amplifier to the slave station the range of the tiltmeters can be adjusted. Before the project began both tiltmeters and slaves were recalibrated (see Table 1).

Tiltmeter Data

Tiltmeter number	Assigned slave	Range in degrees
101	1	$\pm$ 6
103	3	$\pm$ 6
104	4	$\pm$ 6
105	0	$\pm$ 6
106	2	$\pm$ 6
107	7	$\pm$ 1
108	6	$\pm$ 1
109	5	$\pm$ 1

Any combination of slave and tiltmeter may be used providing that the calibration parameters are entered in the master program.

The tilts may be read directly from the tiltmeter using a voltmeter with appropriate adapter using the formular:

$$\alpha = (r+\tau T)/K$$

where α is the tilt, r is the reading, T the temperature, K and τ are the conversion and temperature coefficients (see Table 1). Two readings may be taken from each tiltmeter (one from each axis). When the tiltmeter is read remotely the master program applies corrections that further take into account the gain of the slave input amplifier, the temperature dependency of this amplifier and the expected drift of the tiltmeter with time.

Tiltmeters are the least rugged part of the system and (especially after calibration) are treated with extreme care to avoid impacts. They were transported to the site as hand luggage. Since the slave station uses an 8 bit resolution analogue to digital converter $2^8=256$ signal states may be resolved. Thus if a ± 1 degree range is employed the resolution is 2/256 degrees which is slightly better than 30" of arc. All tiltmeters (with the exception of 109 which wasn't used) had accuracy and stability which is much better than this over a 40 day test period.

PRELIMINARY TEST RESULTS

The system was installed and tested between August 25 and 30, 1985. Present were M.Y. Fisekci, N.J. Stuart and C. Clark of CANMET/CRL and B. Kurz, A. Makosinski and A. Chrzanowski.

THE MASTER STATION

The master station was installed in the offices of the Syncrude geotechnical group (Fig. 1). The roof of this building has good visibility for highwall sites and reasonable visibility to the tailings area. Coaxial cables from the roof mounted antennae to the master station will attenuate the (RF) signals if too long thus some thought was given to the routing of these and the positioning of the master station. Yagi type antennae were used. These are directional in nature thus two had to be used. In general the highwall antenna is left connected to the system; the tailings one being connected for isolated readings (Fig. 2-4). It is intended to modify the system such that these may be switched under software control.

Table 1 - Tiltmeter and slave calibration parameters

(a) Tiltmeter parameters

Tiltmeter No.	Conversion Coeff. K(mV/")		Temperature Coeff. (mV/°C)	
	Axis A	Axis B	Axis A	Axis B
101	0.24186	0.24189	1.0	0.0
103	0.23093	0.23129	0.0	0.0
104	0.22996	0.23122	0.4	0.7
105	0.23038	0.23138	0.0	1.0
106	0.23205	0.230.7	0.4	0.4
109	1.3813	1.3800	-8.0	-10.0
108	1.3824	1.3776	+3.3	+14.5
107	1.3784	1.3858	+1.0	+4.2

(b) Slave parameters

Slave No.	Gain G		Time drift (1/°C)	Offset (mV/°C)
	Axis A	Axis B		
0	-6.24	-6.43	0.0018	-1.0
1	-5.66	-5.65	0.0012	-1.0
2	-5.73	-5.24	0.0020	-0.9
3	-6.05	-6.07	0.0012	-0.8
4	-5.59	-5.66	0.0031	-1.0
5	+1	+1	0	0
6	+1	+1	0	0
7	+1	+1	0	0

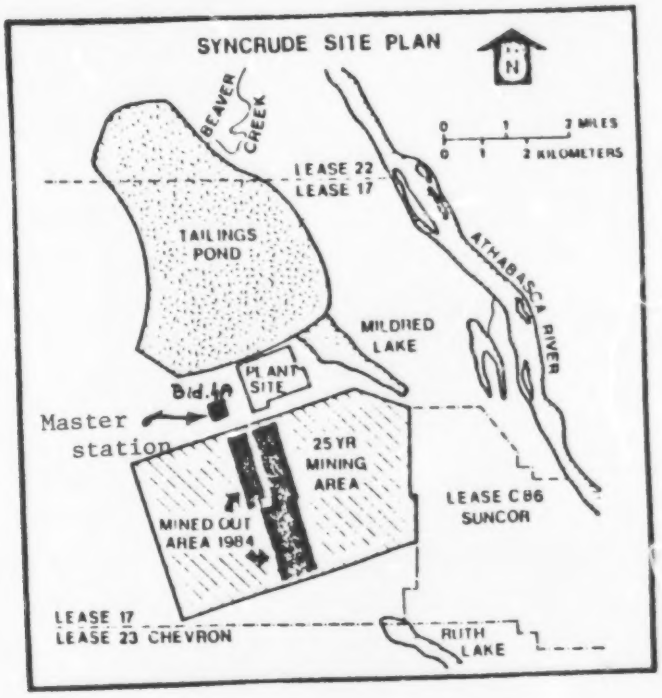

Fig. 1 - Location of master station in relation to mining and tailing areas

Fig. 2 - Antenna and tiltmeter position in front of dragline

Fig. 3 - Service road for tailing and antenna location

Fig. 4 - Structuring and reclamation of tailing

THE HIGHWALL SITE

Five tiltmeter mounts had been prepared prior to the visit by Syncrude staff. These consisted of 3 m boreholes with the tiltmeter mounts cemented in.

The results given in Table 2 show part of the output from the successful integration of slaves 6 and 7 during a 14 hour test. Transmission was over 3 km using small omni-directional "rubber ducky" antennae of the style used on walky-talkies. No problems were caused by interference from nearby heavy electrical equipment or other VHF transmissions. Keeping good intervisibility with the master-station (or near intervisibility) was a concern, however. As the dragline proceeds along the highwall the distance may increase to 5 km and directional antennae may be required. One has now been fitted to slave 6. The procedure calls for leap-frogging the tiltmeters perhaps twice per day, depending on dragline advance. In this procedure the slave closest to the dragline, which has become too close, is moved to a new position (now furthest from the dragline). The tiltmeter mounting has been redesigned to made the movement and resetting of the tiltmeters quick and convenient.

During the extended test period (two months), S. Tan of Syncrude highwall geotechnical group will be responsible for this area of the operation.

THE TAILINGS SITE

Syncrude divides the tailings dam into "sectors". The sector chosen for study is 6-7 km from the master-station and facing away from it. This presents a problem of distance and visibility. Since these slaves are static, once a location and antenna position is found that is satisfactory it may be assumed that communication will continue until the dam is heightened. In general, it has been found that communication will be achieved if the slave is either within a few meters of the top of the dam or it is sufficiently far from the base of the dam that the grazing angle of the waves passing the top of the dam allows diffraction. The area of greatest interest is close to the base of the dam, however, and this might require 150 m tiltmeter-slave station cables. Fortunately accelerometer tiltmeters have a relatively high signal voltage (0-5v in this example) thus such cable may prove practical. The long term solution is probably to put the antennae on a

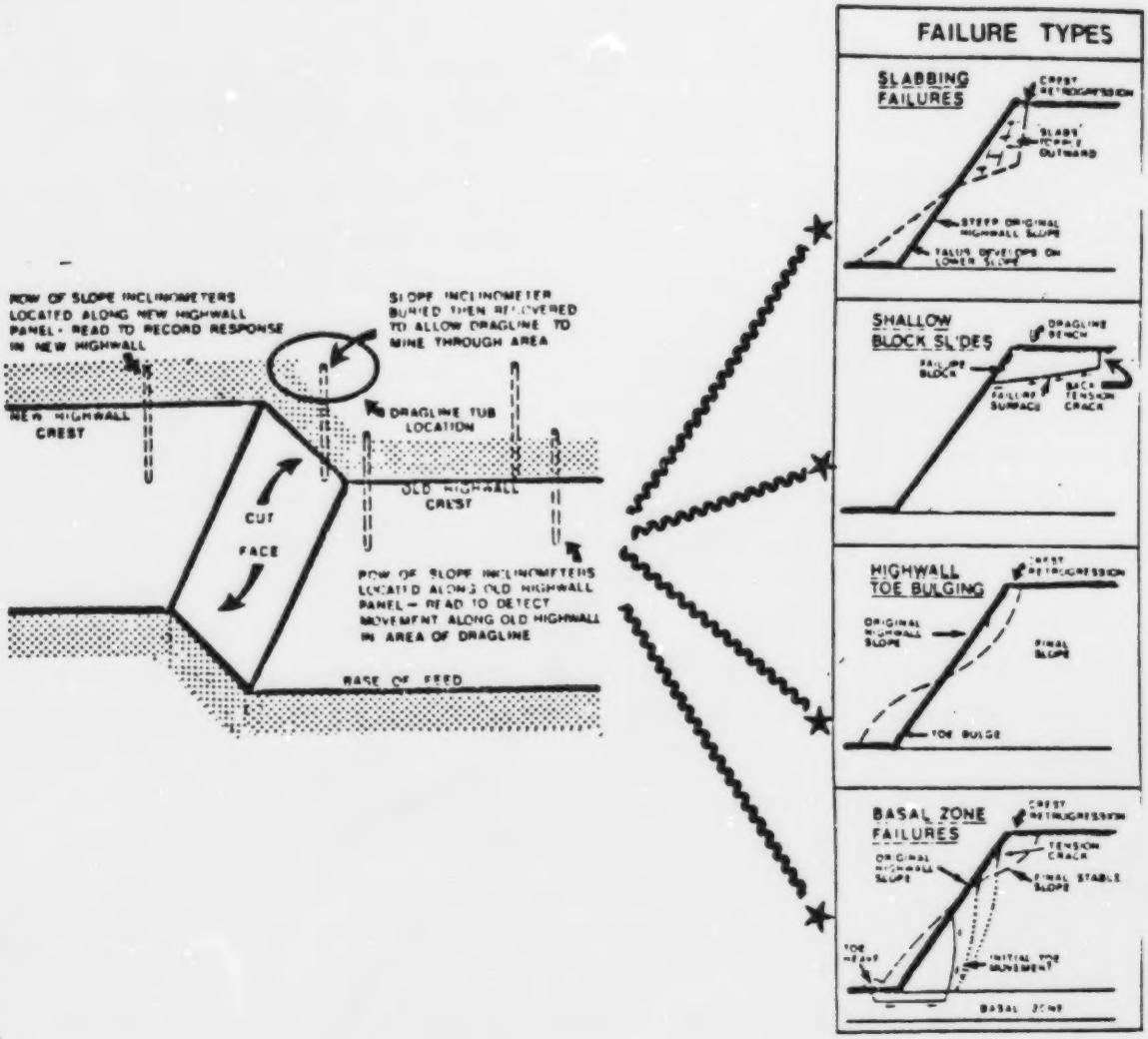
ROW OF SLOPE INCLINOMETERS LOCATED ALONG NEW HIGHWALL PANEL - READ TO RECORD RESPONSE IN NEW HIGHWALL
SLOPE INCLINOMETER BURIED THEN RECOVERED TO ALLOW DRAGLINE TO MINE THROUGH AREA
NEW HIGHWALL CREST
DRAGLINE TUB LOCATION
OLD HIGHWALL CREST
CUT FACE
ROW OF SLOPE INCLINOMETERS LOCATED ALONG OLD HIGHWALL PANEL - READ TO DETECT MOVEMENT ALONG OLD HIGHWALL IN AREA OF DRAGLINE
BASE OF FEED
FAILURE TYPES
SLABBING FAILURES
SHALLOW BLOCK SLIDES
DRAGLINE BENCH
BACK TENSION CRACK
HIGHWALL TOE BULGING
ORIGINAL HIGHWALL SLOPE
FINAL SLOPE
TOE BULGE
BASAL ZONE FAILURES
TENSION CRACK
FINAL STABLE SLOPE

Fig. 5 - Boreholes drilled for tiltmeter/inclinometer application and types of failure at the highwall

Table 2 - Sample of the test results on the dragline

***** SCAN STARTED		TIME	DATE: 08-29-1985 ID	CHO	TILTA	TIME: 02:21 TILTB	TEMP	REPETITIVE SCAN 60 MIN +VB1	-VB2	+VB3	TEST
CALL	6	02:21	6	-0.00	-130	1497	4.8	13.0	-13.0	13.0	2.50
CALL	7	02:21	7	-0.04	1081	-1167	5.7	12.4	-12.4	12.4	2.42
CALL	6	02:21	6	-0.00	-129	1528	5.1	13.0	-12.9	13.0	2.50
CALL	7	02:21	7	-0.04	1081	-1167	5.7	12.4	-12.4	12.3	2.42

***** SCAN STARTED		TIME	DATE: 08-29-1985 ID	CHO	TILTA	TIME: 03:21 TILTB	TEMP	REPETITIVE SCAN 60 MIN +VB1	-VB2	+VB3	TEST
CALL	6	03:21	6	-0.00	-131	1547	4.3	13.0	-13.0	13.0	2.50
CALL	7	03:21	7	-0.04	1165	-1253	5.1	12.4	-12.4	12.3	2.42
CALL	6	03:21	6	-0.00	-131	1550	4.6	13.0	-13.0	13.0	2.50
CALL	7	03:21	7	-0.04	1080	-1197	5.1	12.4	-12.4	12.3	2.42

***** SCAN STARTED		TIME	DATE: 08-29-1985 ID	CHO	TILTA	TIME: 04:21 TILTB	TEMP	REPETITIVE SCAN 60 MIN +VB1	-VB2	+VB3	TEST
CALL	6	04:21	6	-0.00	-103	1491	4.3	13.0	-13.0	13.0	2.50
CALL	7	04:21	7	-0.04	1052	-1140	5.1	12.4	-12.4	12.3	2.42
CALL	6	04:21	6	-0.00	-75	1519	4.3	13.0	-12.9	13.0	2.50
CALL	7	04:21	7	-0.04	1080	-1197	5.1	12.3	-12.4	12.3	2.42

***** SCAN STARTED		TIME	DATE: 08-29-1985 ID	CHO	TILTA	TIME: 05:21 TILTB	TEMP	REPETITIVE SCAN 60 MIN +VB1	-VB2	+VB3	TEST
CALL	6	05:21	6	-0.00	-131	1491	4.3	13.0	-13.0	13.0	2.50
CALL	7	05:21	7	-0.04	1024	-1169	5.1	12.4	-12.4	12.3	2.42
CALL	6	05:21	6	-0.00	-160	1547	4.3	13.0	-12.9	13.0	2.50
CALL	7	05:21	7	-0.04	1080	-1169	5.1	12.3	-12.4	12.3	2.42

***** SCAN STARTED		TIME	DATE: 08-29-1985 ID	CHO	TILTA	TIME: 06:21 TILTB	TEMP	REPETITIVE SCAN 60 MIN +VB1	-VB2	+VB3	TEST
CALL	6	06:21	6	-0.00	-131	1491	4.3	13.0	-13.0	13.0	2.50
CALL	7	06:21	7	-0.04	1052	-1168	5.4	12.4	-12.4	12.3	2.42
CALL	6	06:21	6	-0.00	-160	1519	4.3	13.0	-12.9	13.0	2.50
CALL	7	06:21	7	-0.04	1024	-1196	5.4	12.3	-12.4	12.3	2.42

short tower. Ideally one might chose to use one slave with a greatly expanded capacity to read sensor channels. Piezometers have been installed and it would be advantageous to read these remotely. This site had not been prepared with tiltmeter mounts thus readings of actual tilts could not be made. However, the slaves were tested and transmitted temperature data. The greatest concern had previously been that the transmitters would not prove powerful enough to span the 7 km distance. In practice they clearly were powerful enough especially when yagi antennae were used.

GENERAL COMMENTS ON THE TESTS

The system was installed with very little modification from the previous contract and worked extremely well given the short time available for installation. It was also clear that the system can be easily adapted to automate more of the mine's monitoring tasks. This could include down hole tiltmeters and piezometers already in use. A high level of confidence is felt that the system will greatly enhance the efficiency of the monitoring in both the highwall and tailings areas.

CONCLUSION AND RECOMMENDATIONS

Initial field tests at Syncrude oil sand operations indicates that the telemetry system worked well both at mining and tailing sites. The system has the potential for expansion in the following recommended areas:

- Expansion of telemetry system during spring/summer 1986 to cover the entire mining/tailing area depending upon the results from fall/winter 1985/86 field tests.

- Adaptation/expansion of the slave station to monitor other sensors (piezometer/inclinometers etc.) at mining/tailing areas in summer 1986. The extension to monitor greater numbers of sensors per slave and at greater distances.

- Development of CANMET's manpower and laboratory capabilities with physical/numerical modelling facility for prediction and simulation of R & D work on "Highwall and Tailings" stability problems FY 1986-1988.

- The long term goal of monitoring a variety of operational parameters with the system.